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On the Cyclonic Distribution of Rainfall

BY

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DEDICATORY.

However inappropriate the occasion, the author of the following short paper cannot forego the pleasure of expressing a greeting of remembrance and affection to all of those earnest young men and women who have, with a truly scientific and unselfish interest, during several years in the past given time and thought to the work which was necessary for the extraction from the original documents of the data presented on the following few pages.

Ars longa, vita brevis.

Especially does life and its associations seem short to the man in the lecture room. It is his privilge to continually make new and most pleasant acquaintances with open and unbiased young minds and hearts, but it is also his fate to be compelled to part with them, as he feels, altogether too soon, often never to meet them again.

To each and every member of my former classes in Meteorology, and especially to the members of the Weather Club, I extend my thanks, and desire to present a copy of this paper.

J. A. UDDEN.

Augustana College, March 30, 1905.

ON THE CYCLONIC DISTRIBUTION OF RAINFALL.

Some years ago I had the pleasure of hearing a lecture on weather, given by one of the observers of the United States Weather Bureau. The lecturer discussed the distribution of weather in the extra tropical cyclones in America. He described the conditions which characterize the four quadrants of an area of low pressure. He especially emphasized the statement we often find in text-books, that the greatest precipitation occurs in the region which lies some distance to the southeast of the center of an area of low pressure.

A short time after hearing this lecture I had occasion to discuss weather prognostics with a gentleman whose occupation had led him for many years to closely watch the government's forecasts issued at Davenport, Iowa. This gentleman said he had found that storms would usually arrive from six to twenty hours behind the time they were due according to the local forecasts. Otherwise he regarded the predictions as quite reliable and valuable. "When a storm is announced", he said, "it will almost always come, but it is apt to be a little behind time." This statement corroborated an impression which I had myself received. It is the writer's belief that if a careful comparison were made of the forecasts referred to, and of the actual conditions of the weather at Davenport previous to 1896—since which time I have given less attention to the matter–it would be found that the forecasts more frequently missed by announcing storms too early, than too late.

It occurred to me that this delay of the expected storms might be due to some regional or local variation in the features of the passing cyclones, and that it would be desirable to determine, by some statistical method, the actual relation of weather conditions to different parts of the cyclone for this locality. For the purpose of doing this, I made use of a simple devise, which I have since had the satisfaction of seeing employed by others. By marking off eight radii in four concentric circles I plotted twenty-five areas in a figure, which could be used to represent definite separate tracts in a circular storm. The lengths of the radii of the successive circles had the ratios 1: 4: 7: 10 and were taken to represent the same number of hundreds of miles in a composite cyclone two thousand miles in diameter. The construction will be readily understood from the accompanying figures. The radii were drawn at angles of 45°, but were not extented into the inner circle. The figure was so oriented that the four points of the compass would bisect four alternate octants. There were thus three tracts marked off in each octant outside the smallest circle. With this representing the central region of a cyclone, the figure was used to delimit twenty-five fixed areas inside its extent. Tract "1" thus covers a central circle two hundred miles in diameter in the center of a cyclone. Tract "2" covers an area extending from one hundred to four hundred miles away from the center to the north, and lying between radii diverging 22½° on either side. Tract "10" covers the area between the same two radii at a distance from four hundred to seven hundred miles from the centre. Tract "18" lies at a distance from seven hundred to one thousand miles from the centre, and so on, in the other octants.

My method was then simply to take a sufficient number of observations on the weather at Davenport, when this station lay in any one of the twenty-five corresponding tracts of an actual cyclone, and to average these for each tract separately and thus obtain for each separate percentages expressing frequency of certain weather conditions, such as precipitation and cloudiness, resultant wind directions, etc. I averaged these elements of the weather, as observed at 8 A. M., during a period of about five years, taking the data from the daily weather maps. There were nearly a thousand observations in all. These were distributed among the twenty-five tracts somewhat unequally, but it is believed that the number of observations in each tract was large enough to secure a fairly representative average. In other words: the number of times precipitation occurred or cloudiness prevailed was noted when Davenport was located in any one of the designated tracts with reference to the centre of a low area, and also the total number of times the opposite conditions prevailed. From these two figures percentages were obtained showing the comparative frequency of precipitation and cloudiness in each tract. It will be seen that this is only a very simple method of averaging weather conditions for different parts of an area of low pressure. The results can be plotted on a chart.

It was found that precipitation is most frequent at Davenport when the station lies in the tract numbered eight, which is on the west side of the central low. It was also found that precipitation is infrequent in the region to the southeast of the centre, decreasing very rapidly in that direction from the tract numbered eight. From this distribution of precipitation it is evident that if forecasts were made on the supposition that precipitation is greatest on the southeast side of the central low, a large percentage of the predictions would announce the stormy weather ahead of time. For it would often happen that the centre of the low would have to move east some two or three hundred miles before it would bring up that tract, where rains and snow are actually most frequent.

With the aid of some student friends the cyclonic conditions were averaged in a like manner for some more stations, representing four other climatic regions in the United States. It was found expedient to make use of data slightly different from those used in the Davenport cyclone. Thus we combined the observations taken at Amarillo, Dodge City, Wichita, and Oklahoma during the years 1894—1898, obtaining a chart which presumably is characteristic for the cyclonic conditions on the southwest plains. Other charts combined into like averages the observations at Helena, Miles City, Leander, and Boise City for 1899; those taken at nine stations in the Upper Missiouri Valley in 1899; and those taken at Detroit and at Buffalo during the years 1900—1903.

The precentages of precipitation for the several cyclonic tracts in each of the five locations averaged, are given in Table no. 1, below, and in the same way the precentages of cloudiness are shown in Table no. 2 for the same locations, exepting Davenport. Cloudiness was averaged for this station also, but the figures are not now accessible. The same data are plotted in the accompany ing figures.

TABLE NO. 1.

Showing percentages of precipitation in five composite cyclones in different parts of the United States.

Number of tract.	Davenport.	Amarillo, Dodge City, Wichita, and Oklahoma.	Helena, Miles City, Leander, and Boise City.	Missouri Valley Stations.	Detroit and Buffalo.
1	26	3	0	20	44
2	21	14	17	21	40
3	15	20	10	11	40
4	0	—	6	8	40
5	3	5	0	5	26
6	4	3	3	5	15
7	7	9	3	7	15
8	35	5	13	11	26
9	17	21	16	15	33
10	17	21	18	20	25
11	8	19	6	20	18
12	8	13	14	6	17
13	6	2	10	2	18
14	4	2	6	5	5
15	4	8	4	2	0
16	10	6	5	5	34
17	0	21	20	6	25
18	17	18	1	8	9
19	19	6	12	9	8
20	2	6	8	8	9
21	2	6	5	2	6
22	22	6	2	3	—
23	7	7	2	4	0
24	6	7	3	4	1
25	0	6	16	3	0

TABLE NO. 2.

Showing precentages of cloudiness in four composite cyclones in different parts of the United States.

Number of tract.	Amarillo, Dodge City, Wichita, and Oklahoma.	Helena, Miles City, Leander, and Boise City.	Missouri Valley Stations.	Detroit and Buffalo.
1	49	48	60	93
2	57	60	77	93
3	69	46	66	93
4	38	37	49	98
5	37	42	48	77
6	26	55	47	75
7	36	47	47	72
8	67	54	66	92
9	69	45	68	93
10	53	51	12	79
11	68	36	66	75
12	54	56	49	76
13	30	37	34	55
14	28	36	38	58
15	33	36	33	81
16	42	45	36	69
17	60	63	41	71
18	64	22	59	82
19	59	45	51	77
20	38	41	34	53
21	28	26	32	65
22	35	33	35	—
23	36	41	36	80
24	23	36	30	56
25	38	49	27	50

Although the data used for these different averages are not exactly of the same kind, it is believed that these tables and charts are quite comparable, and that they roughly indicate the cyclonic features which are characteristic for each region. They show clearly that the area of the greatest rain- and snowfall is not in the same position with regard to the centres of low areas in different climatic regions. In every case it is eccentric and lies to the west, northwest, north or northeast, in the cases studied, but in no instance to the southeast.

Several features shown in these charts suggest further inquiries. In the two charts for the semi-arid regions in the southwest and the west, precipitation is most frequent in a crescentic tract on the north side of the central low pressure. To what extent is this characteristic of the cyclones in the west?

In the two charts representing conditions in the region of the northern part of the central plains, the area of the greatest precipitation has a sigmoid shape. Is this a constant feature for the region, and, if so, what is its cause?

In the Davenport charts precipitation as well as cloudiness is unexpectedly high in the southernmost tract. Rain and snow are almost as frequent when a low centres three hundred miles north of Lake Superior, as when it lies at Davenport. A study of the conditions which bring about this unexpected precipitation may throw some new light on cyclonic conditions in the interior.

The purpose of this paper is merely to call attention to the method of averaging. It is a truly statistical method which promises a more accurate knowledge of cyclonic conditions than we have had before. Its application will involve a great deal of work. The averages given here pertain only to the conditions for the morning hour. If similar averages could be made for an afternoon or for an evening hour, for the same places and periods, it is not unlikely that differences would appear. Again, it is to be expected that summer and winter cyclones are unlike, and it is believed that there are differences among the cyclones coming along different paths. If this is true, it ought to be shown in such averages as those presented in the above tables.

A study of all regional, seasonal, and other differences by some such accurate method of averaging can hardly fail to add some important items to our knowledge of cyclonic disturbances. It may be used for any of the elements of the weather. Thus, in the charts which follow, the prevailing wind directions are indicated by arrows, and the relative persistence of the given direction is indicated by the relative length of these arrows.

NOTE: In the figures numbered 2, 3, 4, 5 and 6, the shading represents different percentages of precipitation as follows:

Solid black,	40°|o, and above.
Crossed parallel lines,	30—39°|o
Parallel lines,	20—29°|o
Interrupted parallel lines,	10—19°|o
No shading, less than	10°|o

and in the figures numbered 7, 8, 9 and 10 percentages of cloudiness are indicated thus:

Parallel lines,	75°|o, and above.
Interrupted parallel lines,	50—74°|o
No shading, less than	50°|o

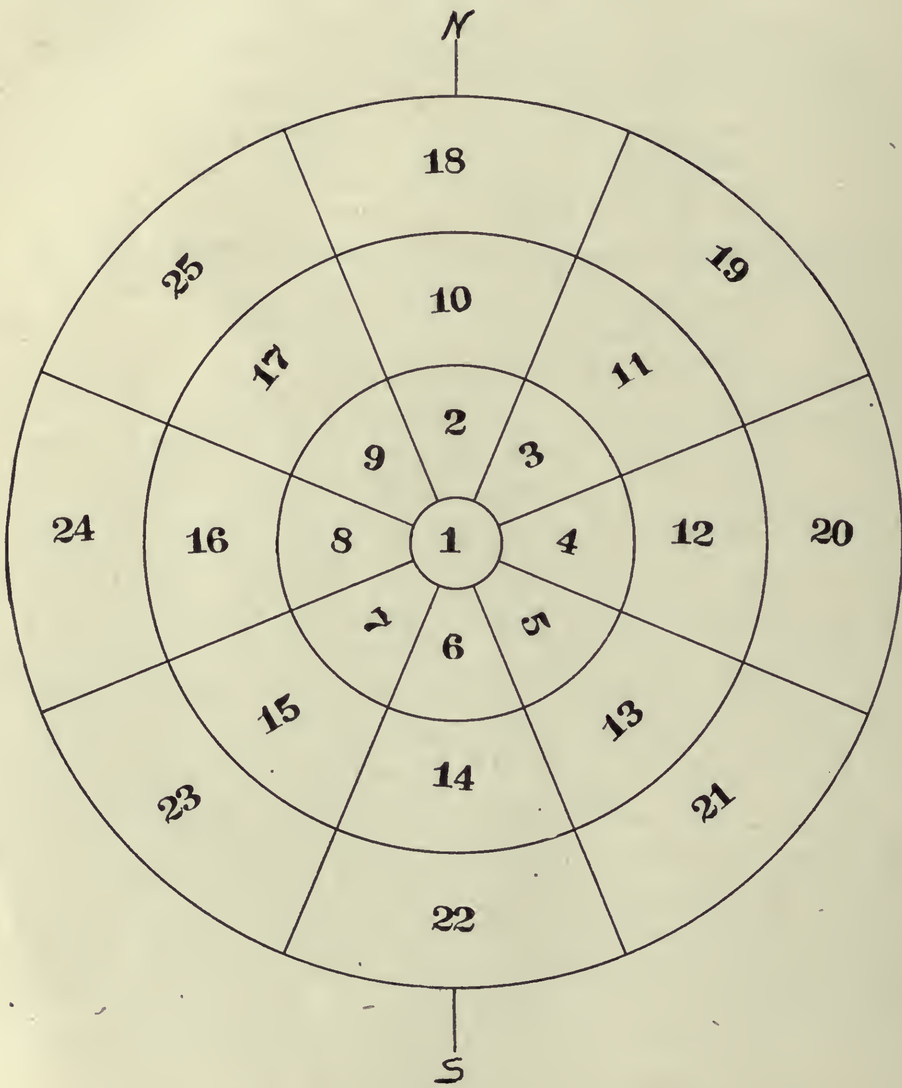

Fig. 1. Showing the location of each of the twenty-five tracts as averaged in each cyclonic area. The numbers are those given under the columns "number of tracts" in the preceeding tables.

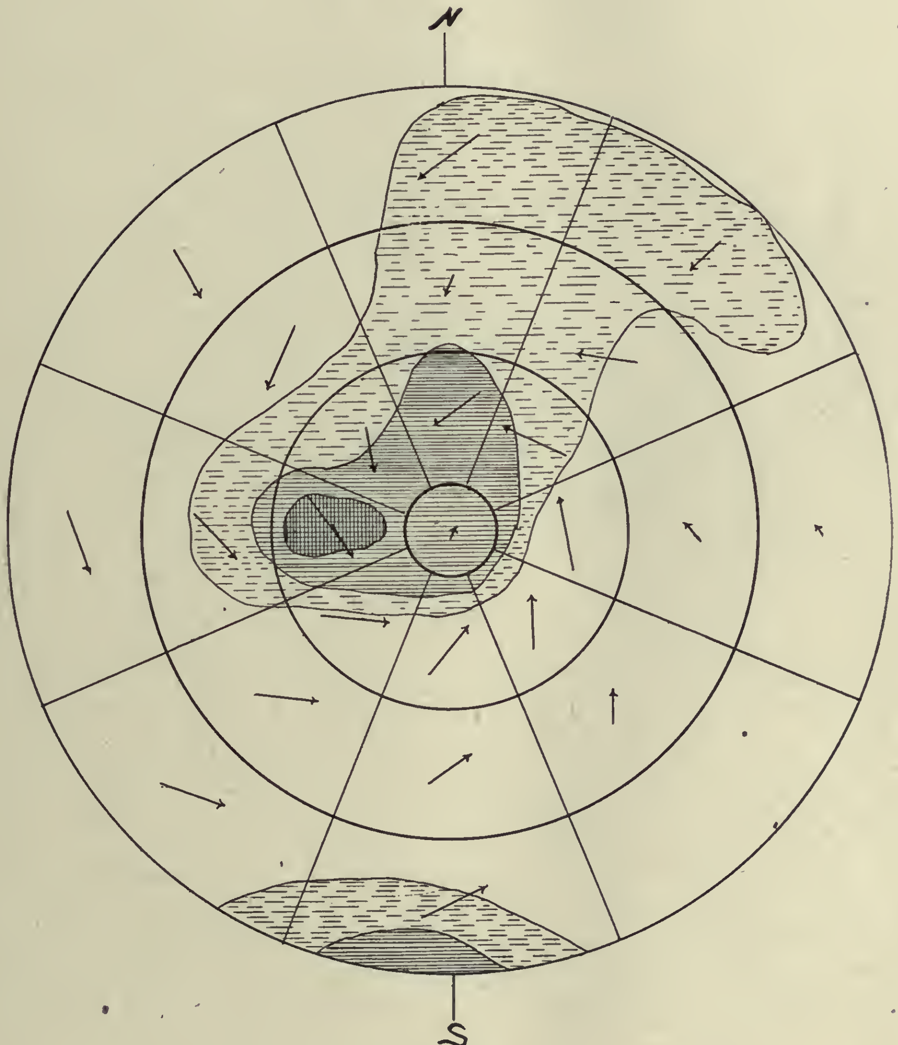

Fig. 2. Showing the distribution of precipitation and wind directions in a composite cyclone, based on the 8 A. M. observations taken at Davenport during the years 1893—1897.

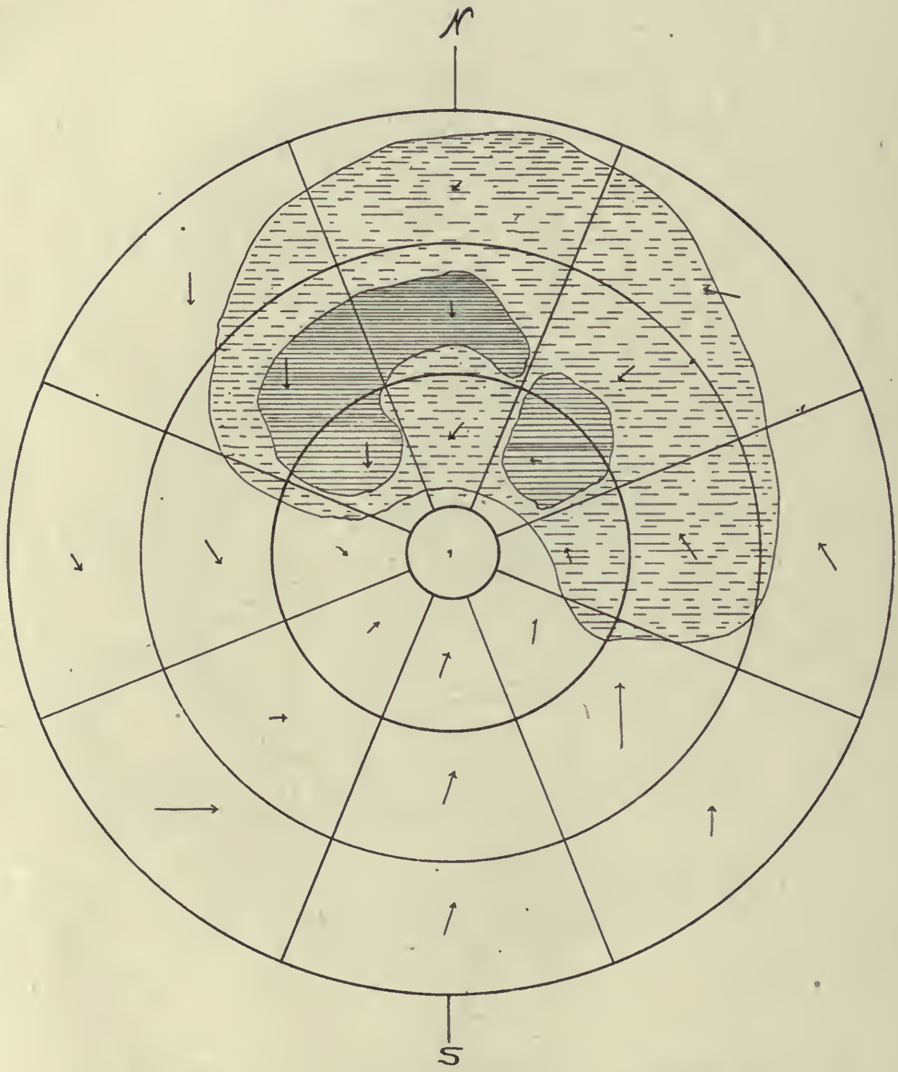

Fig. 3. Showing the distribution of precipitation and wind directions in a composite cyclone, based upon the 8 A. M. observations taken at Amarillo, Dodge City, Wichita and Oklahoma during the years 1894—1898.

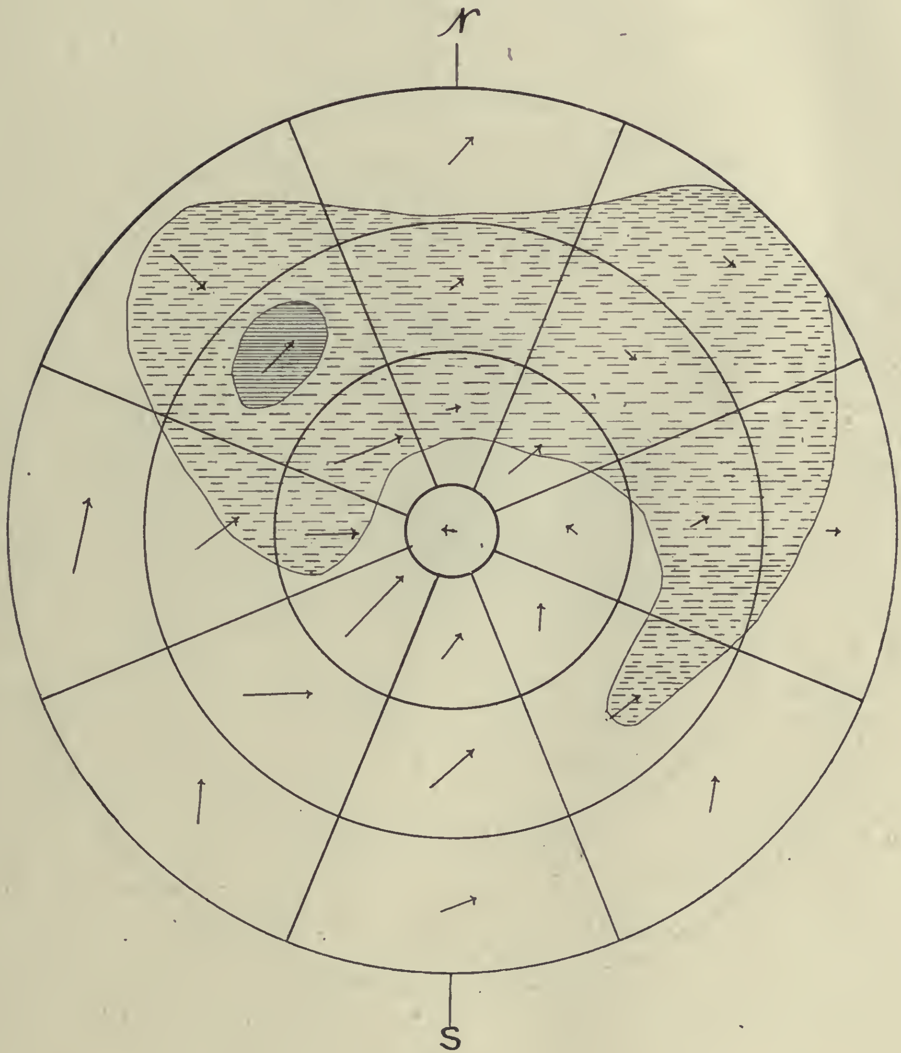

Fig. 4. Showing the distribution of precipitation and wind directions in a composite cyclone, based upon the 8 A. M. observations taken at Helena, Miles City, Leander and Boise City in 1899.

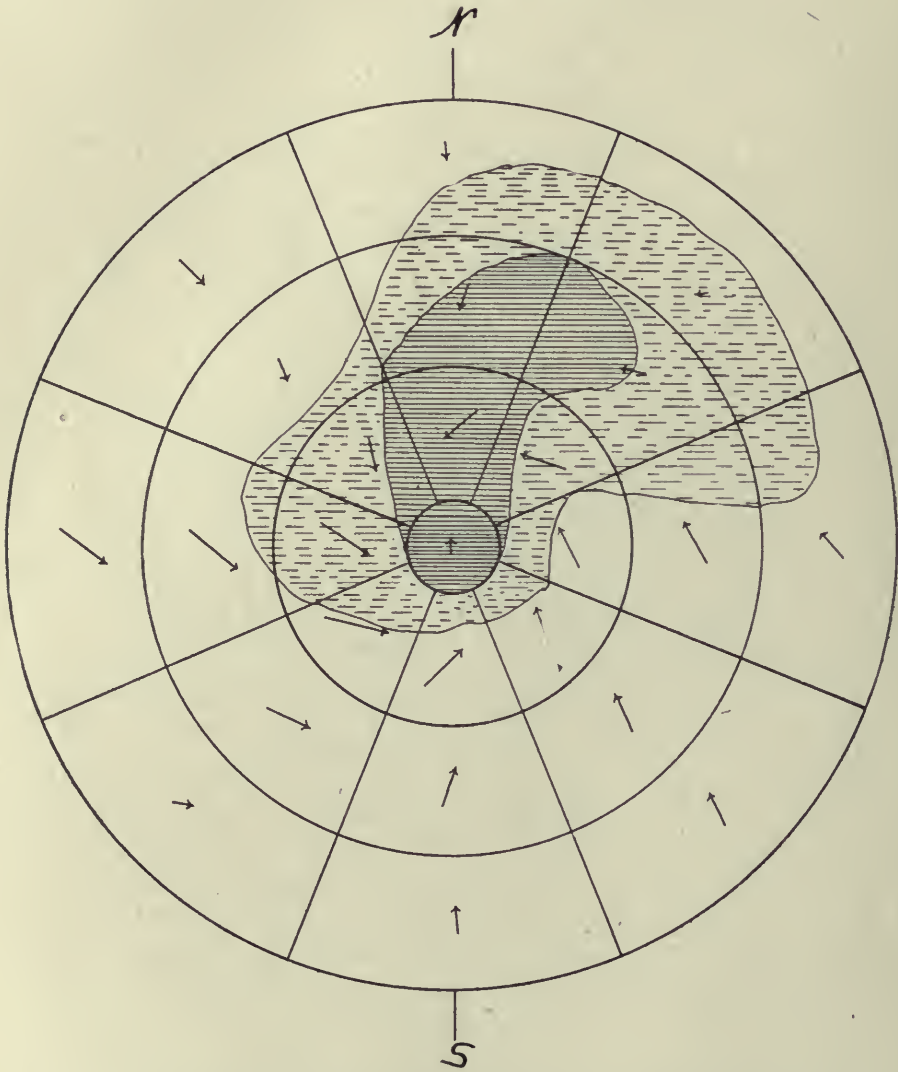

Fig. 5. Showing the distribution of precipitation and wind direction in a composite cyclone, based upon the 8 A. M. observations taken at all the stations in the Upper Missouri Valley during 1899.

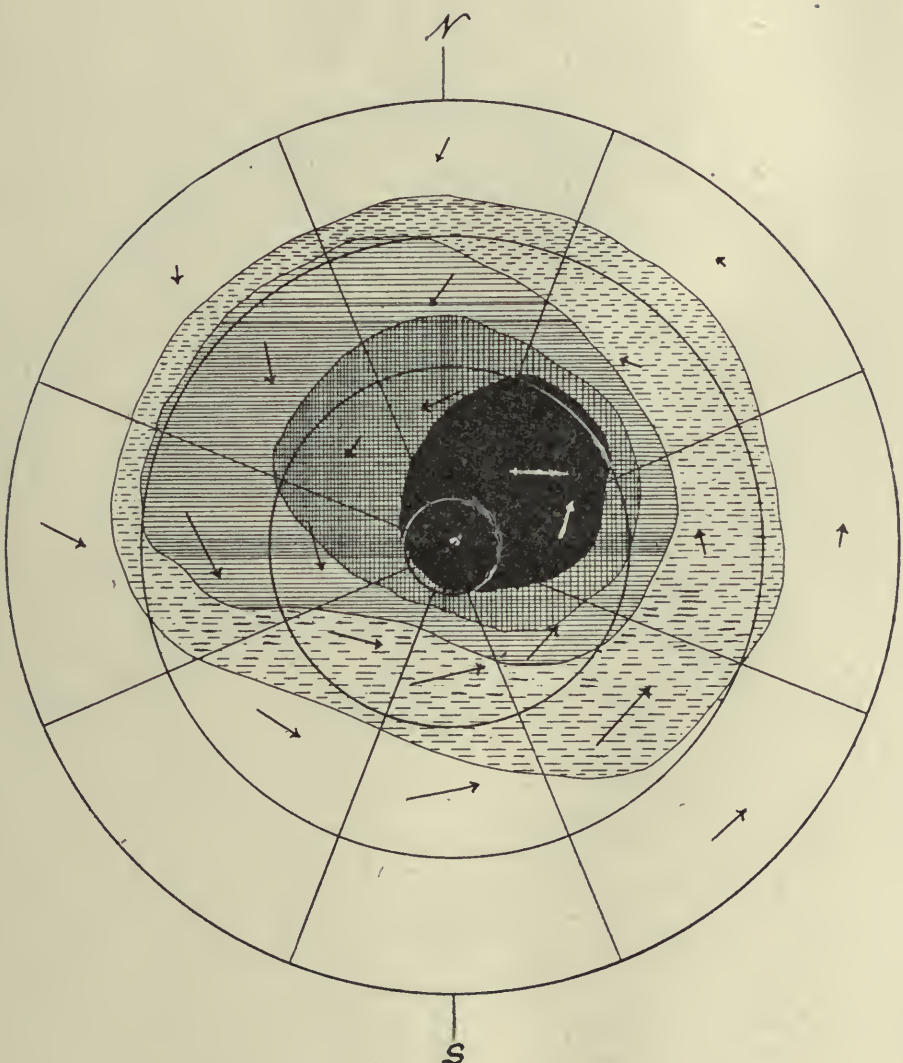

Fig. 6. Showing the distribution of precipitation and wind directions in a composite cyclone, based on the 8 A.M. observations taken at Detroit and Buffalo during the years 1900—1903.

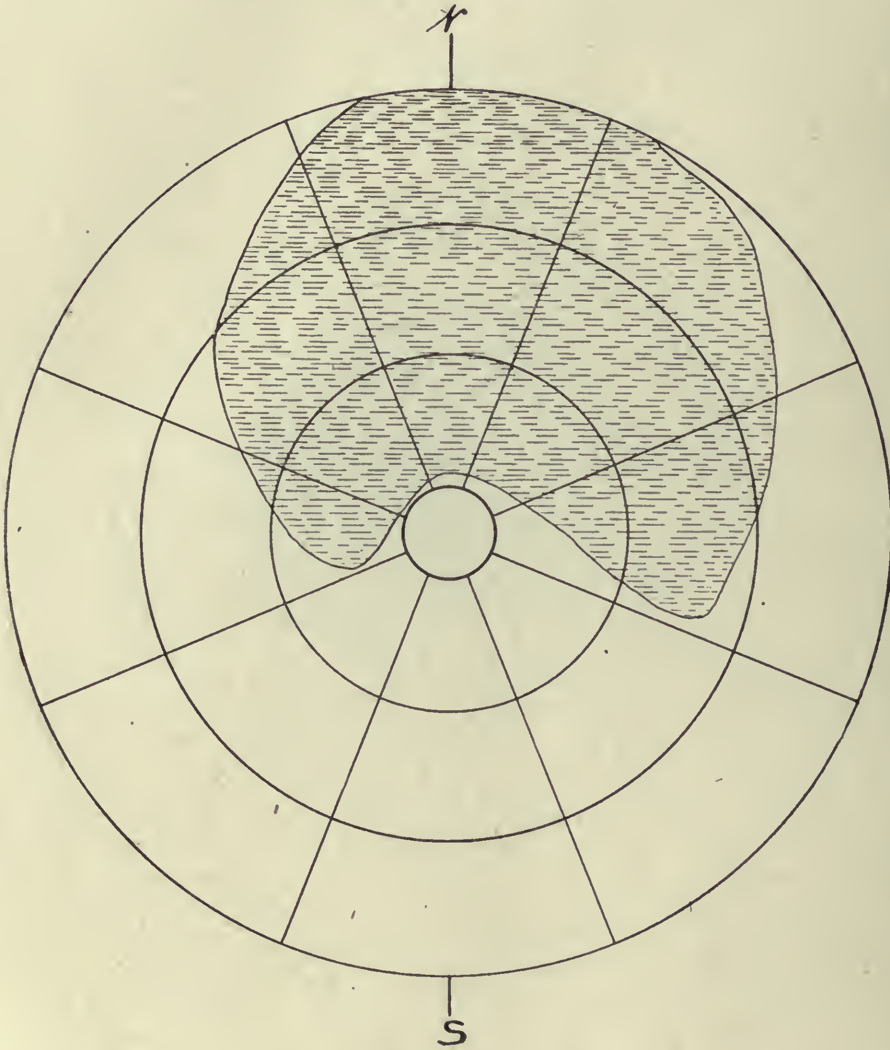

Fig. 7. Showing the distribution of cloudiness in a composite cyclone, based on the 8 A. M. observations taken at Amarillo, Dodge City, Wichita and Oklahoma during the years 1894—1898.

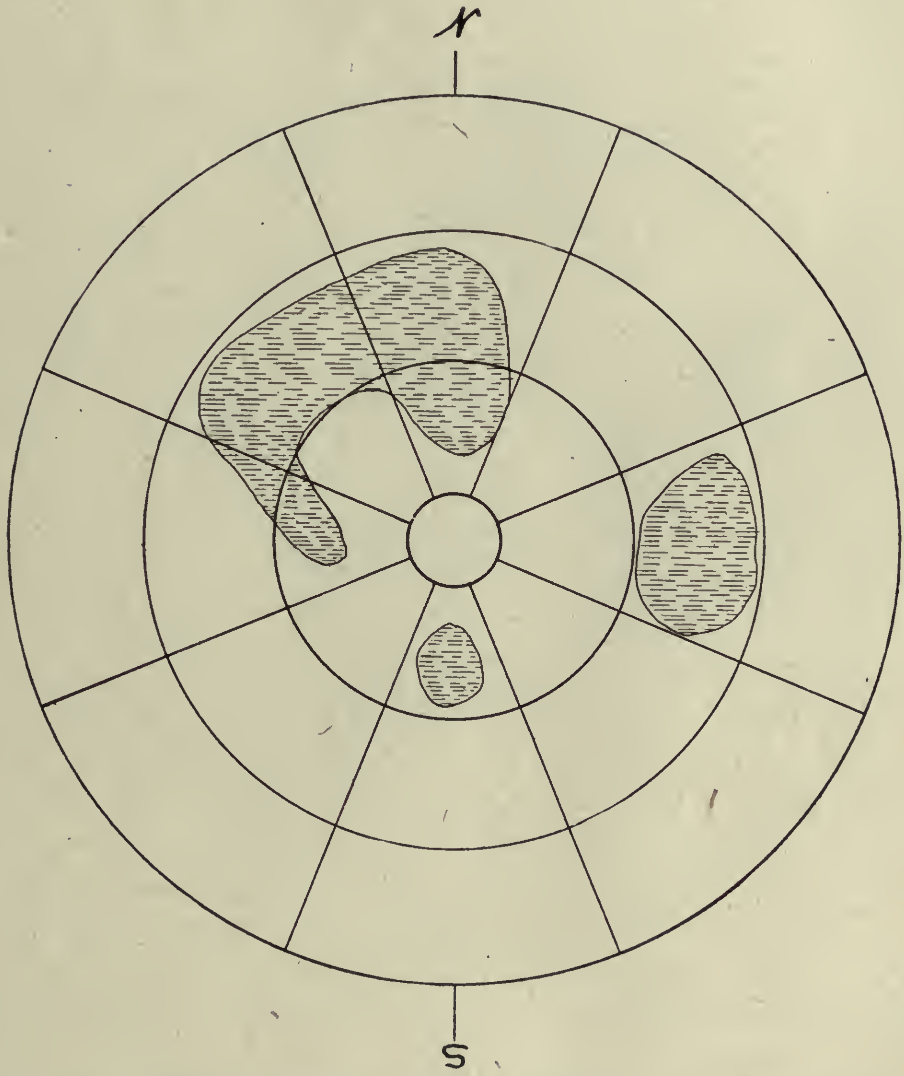

Fig. 8. Showing the distribution of cloudiness in a composite cyclone, based on the 8 A. M. observations taken at Helena, Miles City, Leander and Boise City in 1899.

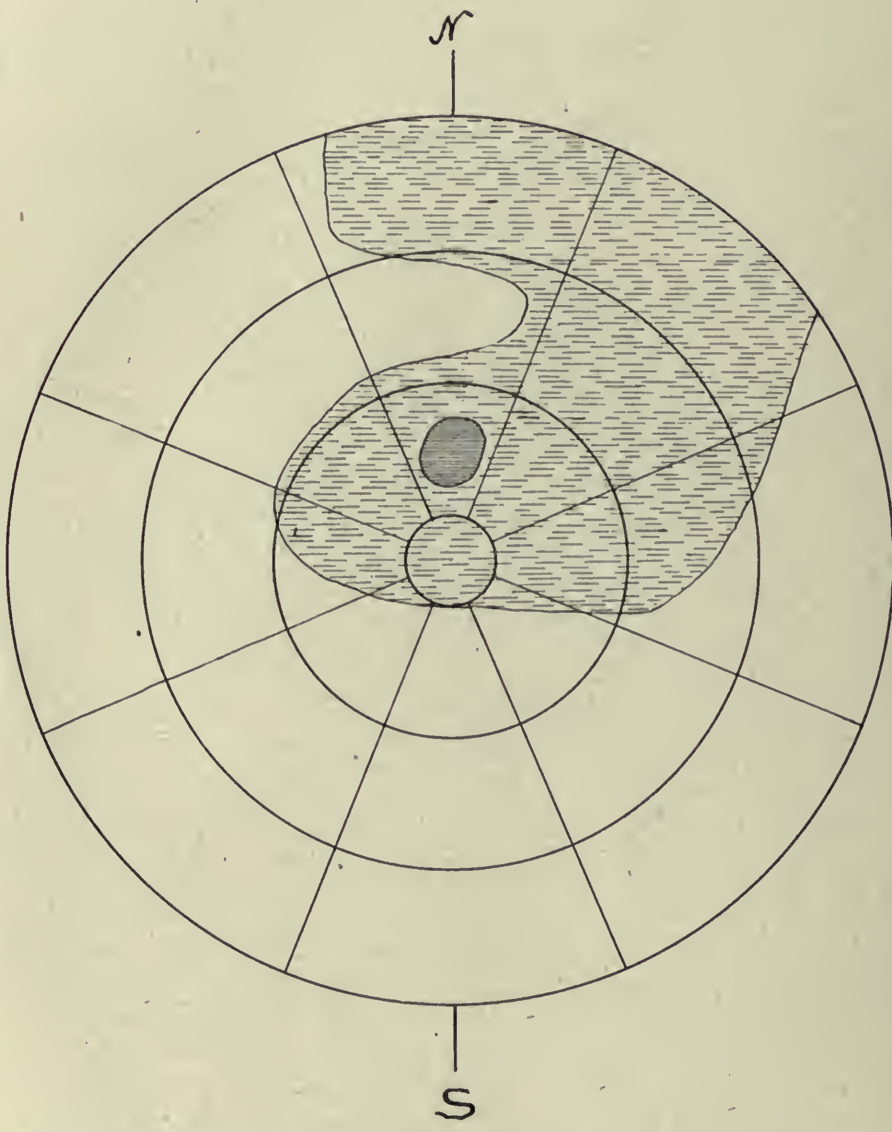

Fig. 9. Showing the distribution of cloudiness in a composite cyclone, based on the 8 A. M. observations taken at all the stations in the Upper Missouri Valley during 1899.

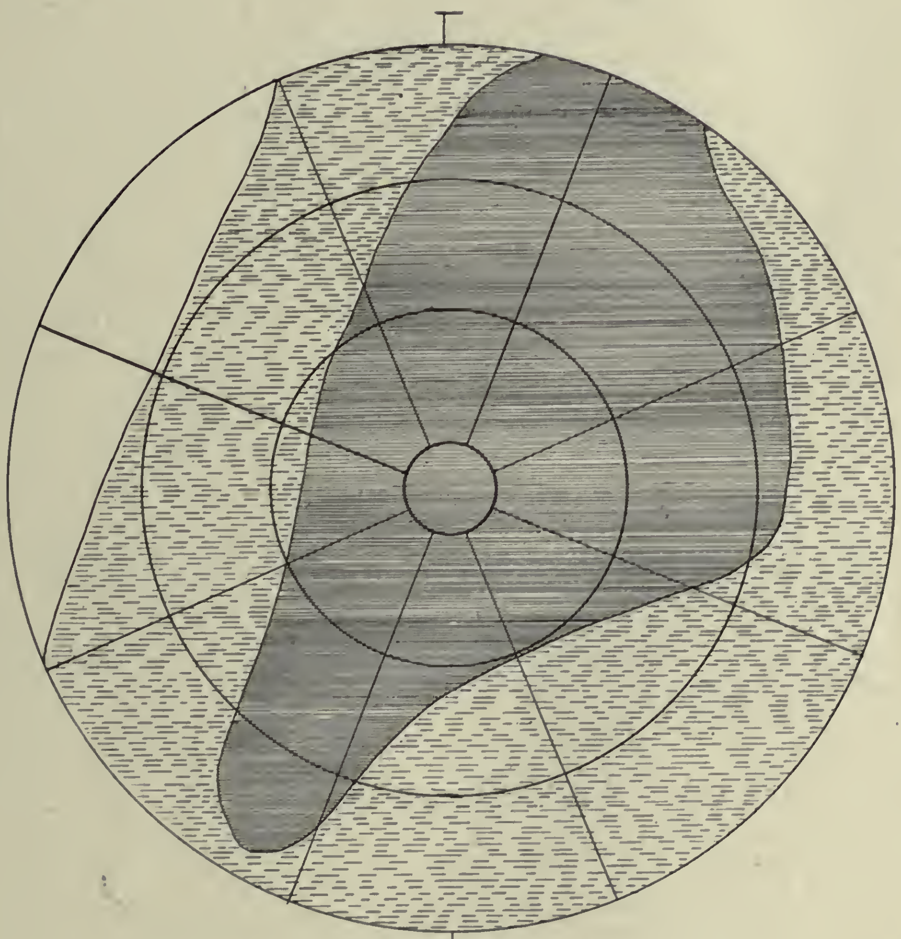

Fig. 10. Showing the distribution of cloudiness in a composite cyclone, based on the 8 A. M. observations taken at Detroit and Buffalo during the years 1900—1903.